Polycyclic Aromatic Hydrocarbons in American Lobster (*Homarus americanus*) and Blue Mussels (*Mytilus edulis*) Collected in the Area of Sydney Harbour, Nova Scotia

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POLYCYLIC AROMATIC HYDROCARBONS IN AMERICAN LOBSTER (*HOMARUS AMERICANUS*) AND BLUE MUSSEL (*MYTILUS EDULIS*) COLLECTED IN THE AREA OF SYDNEY HARBOUR, NOVA SCOTIA

by

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ABSTRACT

Sirota, G.R., J.F. Uthe, D.G. Robinson and C.J. Musial. 1984. Polycyclic aromatic hydrocarbons in American lobster (Homarus americanus) and blue mussel (Mytilus edulis) collected in the area of Sydney Harbour, Nova Scotia. Can. MS Rep. Fish. Aquat. Sci. 1758: vi + 22 p.

Levels of polcyclic aromatic hydrocarbons in American lobster (Homarus americanus) captured in Sydney Harbour, Nova Scotia, during 1980, were high enough to warrant concern regarding the continuation of the commercial fishing of lobster in the area. Based on the results of a survey carried out in 1981 to determine the geographic extent of the contamination, the South Arm of the harbour was closed to commercial lobster fishing in 1982. The levels of benzo[a]pyrene in pooled hepatopancreatic samples from South Arm lobsters ranged between 387-2240 ng/g wet wt (mean = 1030 ng/g) while tail muscle levels ranged from 8-43 ng/g wet wt (mean = 32.3 ng/g). Benzo[a]pyrene levels in lobsters captured in uncontaminated areas were less than 5 ng/g in the hepatopancreas and barely detectible in the tail muscle. Cooking of whole lobster resulted in substantial elevation of polycyclic aromatic hydrocarbon levels in the tail meat, presumably from the hepatopancreas. Blue mussels collected in the area of Sydney Harbour also contained extremely high levels of polycyclic aromatic hydrocarbons.

RÉSUMÉ

Sirota, G.R., J.F. Uthe, D.G. Robinson and C.J. Musial. 1984. Polycyclic aromatic hydrocarbons in American lobster (Homarus americanus) and blue mussel (Mytilus edulis) collected in the area of Sydney Harbour, Nova Scotia. Can. MS Rep. Fish. Aquat. Sci. 1758: vi + 22 p.

Les niveaux d'hydrocarbures aromatiques polycycliques de homards (Homarus americanus) capturés dans le havre de Sydney, en Nouvelle-Écosse, en 1980 étaient suffisamment élevés pour justifier certaines inquiétudes concernant la poursuite d'une pêche commerciale du homard dans cette région. D'apres les résultats d'un relevé effectué en 1981 pour déterminer l'étendue de la contamination, le bras méridional du havre a été fermé à la pêche commerciale du homard en 1982. Les niveaux de benzo[a]pyrène dans des échantillons groupés d'hépatopancréas de homards capturés dans le bras méridional variaient entre 387 et 2 240 ng/g de poids humide (moyenne = 1 030 ng/g de poids humide), tandis que dans le muscle de la queue, les niveaux étaient situés entre 8 et 43 ng/g poids humide (moyenne = 32,3 ng/g de poids humide). Les niveaux de benzo[a]pyrène chez des homards capturés dans les zones non contanimées étaient inférieurs à 5 ng/g de poids humide dans l'hépatopancréas et à peine détectables dans le muscle de la queue. La cuisson du homard entier cause une élévation substantielle des niveaux d'hydrocarbures aromatiques polycycliques dans la chair de la queue, probablement en provenance de l'hépatopancréas. Des moules bleues recueillies dans la région du havre de Sydney contenaient également de hauts niveaux d'hydrocarbures aromatiques polycycliques.

INTRODUCTION

In 1980, 12 non-alkylated polycyclic aromatic hydrocarbons (PAH) were measured in American lobster (Homarus americanus) and blue mussels (Mytilus edulis) collected from Sydney Harbour, Nova Scotia. The PAH levels observed were considered high enough to warrant a more intensive survey encompassing areas ranging from the inner harbour areas (South Arm, Northwest Arm, South Bar) to background areas along both the northeast and southeast coasts of Cape Breton Island, Nova Scotia (Fig. 1). This report will describe the results of these studies.

MATERIAL AND METHODS

Lobster samples were obtained by commercial fishermen, by departmental personnel who set and fished commercial traps, or by scuba divers. Wherever possible, 10 market-size lobsters were sampled. Hepatopancreas (digestive gland) and tail muscle were dissected out of freshly killed lobster within 18 h of capture. The preparation and storage of lobster sample pools, and a detailed description of the analytical methodology used, have been previously described (Sirota et al., 1982). All PAH concentrations are expressed on a wet weight basis.

Lobsters were also sampled from other areas considered by local Fisheries officers to be "clean" (distant from any obvious anthropogenic sources of PAH such as wharves, moorings, etc.,) and "dirty" (close to such sources). For example, the, Morien "dirty" site is close (30 meters) to the Morien wharf, while the "clean" site is approximately 1.5 km away from the wharf complex. The Morien control site is more than 6 km away from the wharf. To determine the effect of cooking, lobsters which had been previously exposed to a synthetic mixture of 5 PAH (phenanthrene, fluoranthene, pyrene, triphenylene and perylene) were randomly separated into two groups. One group was then cooked whole ("normal" cooking method) by steaming over boiling distilled water for 10 min. The other group had only the tail cooked after being separated from the body. A small section of the raw tail muscle was taken for analysis prior to cooking. Twenty-five mussels, 20-30 mm in length, were collected from each site (Fig. 2) and allowed to depurate in clean seawater for 16 h to expel pseudo-feces. The mussels were then opened, allowed to drain for 10-15 minutes, and soft tissues separated from the shell. Each sample of 25 pooled soft tissues was then blended using a Polytron homogenizer.

The following abbreviations were used (National Research Council of Canada 1983): Phen - phenanthrene, Flt - fluoranthene, Pyr - pyrene, Tri - triphenylene, B[a]A - benz[a]anthracene, Chry - chrysene, B[e]P - benzo[e]pyrene, B[b]F - benzo[b]fluoranthene, B[k]F - benzo[k]fluoranthene, B[a]P - benzo[a]pyrene, B[ghi]Pe - benzo[ghi]perylene, I[1,2,3-cd]P - indeno[1,2,3,cd]pyrene, Per - perylene.

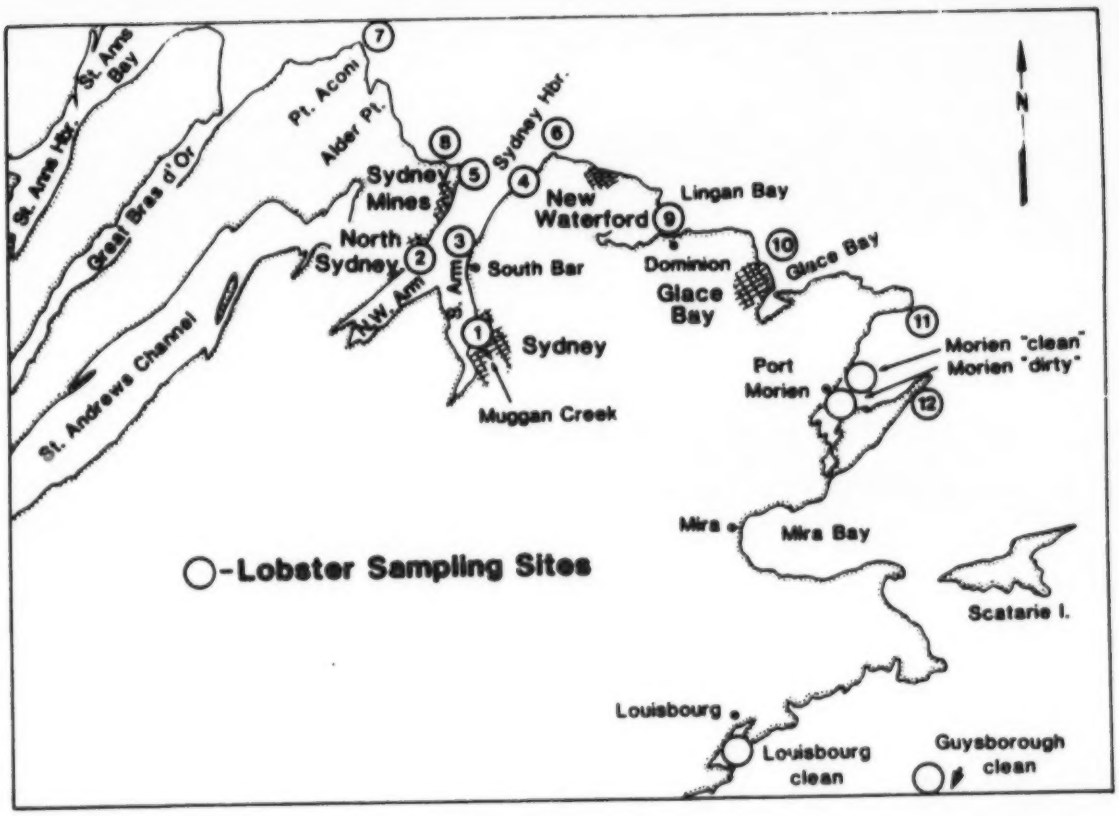

Figure 1. Lobster sampling sites.

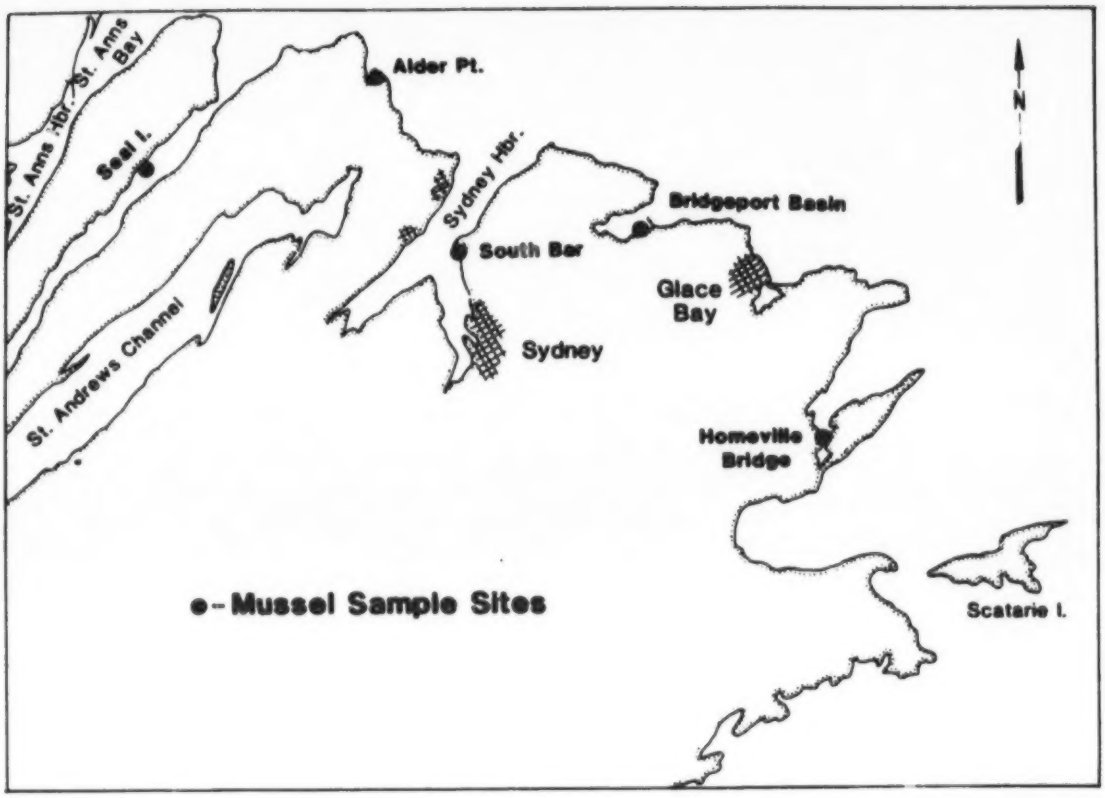

Figure 2. Mussel sampling sites.

RESULTS AND DISCUSSION

Studies by the Canadian Department of the Environment (Matheson et al. 1983) have shown that Muggah Creek (Fig. 1) which drains facilities related to the Sydney Steel Plant (coking ovens, etc.) is the main source of PAH contamination in Sydney Harbour. As can be seen from the data in Tables 1-7 the highest PAH levels were found in lobsters from the South Arm of Sydney Harbour, the site closest to Muggah Creek, and, in general, PAH levels at other sites decreased with increasing distance from South Arm and Muggah Creek. Total PAH levels were also higher in lobsters captured inside Sydney Harbour than in lobsters from other coastal sample locations. Also evident in Tables 1-9 is the difference in the PAH concentrations measured in the two sample pools.

PAH levels in lobster tail muscle were much lower than in the corresponding hepatopancreas, ranging from 10-100 times lower. A detailed discussion of the relationships between hepatopancreas and tail muscle PAH levels has been published (Uthe et al. 1984). Between-animal variance was determined by analyzing individual hepatopancreas and tail muscle from 10 lobsters which had been held for 13 d in clean water following a 3 m exposure to creosoted timbers (Table 10). The animal-to-animal relative standard deviations of individual PAH ranged from 48%-86% in hepatopancreas and from 21%-70% in tail muscle. These data demonstrate the inherent heterogeneity of hepatopancreas and tail muscle PAH levels and indicate that a relatively large animal-to-animal variation in PAH levels exists among animals even when held under similar conditions. A similar or higher variation would be expected in lobsters taken from the relatively more heterogenous area, Sydney Harbour and other coastal areas.

Using B[a]P, a carcinogenic PAH (National Academy of Sciences, 1972), as an example, levels in South Arm lobster (Table 1) hepatopancreas ranged from 387-2240 ng/g (wet wt) with an overall mean of 985$\pm$671 (S.D., N=8). B[a]P levels in equivalent tail muscle tissue pools from South Arm ranged from 8.0-43 ng/g with a mean of 32$\pm$12.6 (S.D., N=8). BaP levels in lobsters taken from Northwest Arm (Table 2) were considerably lower than South Arm values with B[a]P in pooled hepatopancreas ranging from 35-147 ng/g with an overall mean of 87$\pm$63 (S.D., N=4). Tail muscle B[a]P levels ranged from 2-6.7 ng/g with a mean of 4.3$\pm$2.0 (S.D., N=4).

Apart from wind and tidal effects, there is a gradual movement and mixing of water from both the Northwest Arm and South Arm, past South Bar. BaP levels in lobster from South Bar (Table 3) were lower than levels in South Arm samples. B[a]P concentrations in South Bar lobster hepatopancreas ranged from 50-102 ng/g with a mean of 70$\pm$24 (S.D., N=3).

Flt is an example of a non-carcinogenic PAH (National Academy of Sciences, 1972), typically formed during combustion and pyrolytic operations, and levels of this PAH followed a trend similar to B[a]P with the highest levels occurring in South Arm lobster (mean $\pm$ S.D. in hepatopancreas and tail muscle pools respectively 11300$\pm$3550 ng/g and 382$\pm$109 ng/g). Corresponding mean $\pm$ S.D. values in hepatopancreas and tail muscle respectively were 4050$\pm$2780 ng/g and 135$\pm$29 ng/g for Northwest Arm and 1810$\pm$485 ng/g and 82$\pm$26 ng/g for South Bar.

Table 1. PAH concentrations (ng/g wet wt) in South Arm lobster ('A' pool, 'B' pool).

	Hepatopancreas							
PAH	MAY 1981		OCTOBER 1981		MAY 1982		AUGUST 1982	
Phen	15200	16400	2900	3470	5588	2970	4670	5074
Flt	7050	7370	12400	10700	15200	12400	8790	16800
Pyr	7800	9110	6710	2940	13100	9150	8353	14600
Tri	21300	21900	23100	14900	37700	23800	21000	34300
B[a]A	9090	9690	23400	13400	32700	18000	18600	35700
Chry	7670	7850	5050	2820	1030	252	584	765
B[e]P	3820	3580	9330	5060	3600	1990	5080	10300
B[b]F	900	986	2350	1640	3820	2460	3000	5260
B[k]F	225	234	588	392	955	640	620	1190
B[a]P	433	387	1000	637	1430	930	1180	2240
B[ghi]Pe	1140	896	463	493	769	475	883	1350
I[1,2,3-cd]P	1720	1500	855	787	739	525	543	735
	a		Tail muscle					
Phen	760		465	405	200	185	88	111
Flt	250		545	435	420	442	254	325
Pyr	125		265	135	333	70	206	297
Tri	800		330	295	690	600	805	411
B[a]A	200		604	352	678	500	408	407
Chry	135		79	51	20	15	19	17
B[e]P	75		165	102	35	35	103	131
B[b]F	22		78	51	835	72	725	68
B[k]F	6		25	14	26	19	19	20
B[a]P	8		40	23	43	33	38	41
B[ghi]Pe	25		31	14	20	10	20	22
I[1,2,3-cd]P	46		45	33	40	33	18	18

a - analyzed as 1 pool of 6 animals

Table 2. PAH concentrations (ng/g wet wt) in Northwest Arm lobster ('A' pool, 'B' pool).

PAH	OCTOBER 1981		MAY 1982	
	Hepatopancreas			
Phen	700	780	1280	980
Flt	3030	2660	8200	2320
Pyr	780	730	2280	2880
Tri	4440	4480	5080	4020
B[a]A	1620	1640	4310	4950
Chry	360	430	160	140
B[e]P	465	415	430	245
B[b]F	190	155	406	540
B[k]F	50	43	110	125
B[a]P	56	35	134	147
B[ghi]Pe	28	18	80	70
I[1,2,3-cd]P	66	38	107	125
	Tail muscle			
Phen	650	530	210	144
Flt	170	145	120	103
Pyr	85	87	21	19
Tri	67	62	385	240
B[a]A	63	34	92	118
Chry	9	6.5	5.5	7
B[e]P	15	16	25	16
B[b]F	10	6	48	13
B[k]F	2.5	1.6	4	3
B[a]P	2	3.5	6.7	5
B[ghi]Pe	1.6	2.4	6	3
I[1,2,3-cd]P	4	3	7	5

Table 3. PAH concentrations (ng/g wet wt) in South Bar lobster ('A' pool, 'B' pool).

PAH	MAY 1981		OCTOBER 1981		MAY 1982		AUGUST 1982	
			Hepatopancreas					
Phen	1900	2460	T[c]	T	755	370	666	1670
Flt	1300	1780	1920	2150	2590	1920	1010	1800
Pyr	830	1350	730	850	1030	670	510	1560
Tri	6180	7130	2520	3850	3450	2550	1030	1370
B[a]A	2620	2930	1890	2150	2290	1590	1240	2530
Chry	3860	4140	585	620	93	72	70	168
B[e]P	1410	1510	635	650	185	127	394	750
B[b]F	274	250	220	225	218	350	176	470
B[k]F	60	57	69	69	68	106	52	94
B[a]P	102	73	50	53	81	80	58	160
B[ghi]Pe	470	410	8	7	1.2	1.5	74	146
I[1,2,3-cd]P	670	610	70	75	61	76	66	148
	a		Tail muscle					
Phen	106		T	T	157	118	170	103
Flt	56		110	125	84	74	64	60
Pyr	nd[b]		32	35	12	13	34	16
Tri	nd		T	T	206	85	34	T
B[a]A	45		44	54	88	101	38	32
Chry	nd		5	6	7.8	4.8	T	T
B[e]P	nd		17	16	31	31	9	12
B[b]F	6		7	7	10	15	4	7
B[k]F	1.7		2	2.5	2.8	3.9	1.2	1.2
B[a]P	1.7		2	2.2	4.7	4.7	2	2.8
B[ghi]Pe	9		4.5	2.5	4.4	4.2	2.2	2
I[1,2,3-cd]P	11		3	3	4	4.8	1.4	1.8

a - analyzed as 1 pool
b - not detected
c - trace

PAH residues in lobsters from Petrie Point (Table 4), Swivel Point (Table 5) and Low Point, sample sites near the mouth of the harbour, though lower than levels in Northwest Arm and South Bar and substantially lower than levels in South Arm lobsters, were quite variable. For example, B[a]P levels in Petrie Point lobster hepatopancreas were 30-145 ng/g while tail muscle levels were 1.3-5 ng/g. Swivel Point and Low Point lobsters also showed a similar variability. Average Flt levels (+ S.D.) in hepatopancreas and tail muscle respectively were 1600+700 ng/g and 69+31 ng/g at Petrie Point, 1430+678 ng/g and 87+46 ng/g at Swivel Point, and 1160+64 ng/g and 114+21 ng/g at Low Point. Coastal current flows are generally toward the southeast. This combined with the tidal cycles may result in complex mixing patterns of Sydney Harbour water and relatively uncontaminated coastal waters. The variability shown in PAH levels at these three sites may, therefore be due to this complex hydrography, lobster movement between the areas, and the large range of PAH values found in lobster (vide supra).

Overall B[a]P and Flt levels in Sydney Harbour lobsters were similar in 1982 and 1981. There were little noticeable differences in B[a]P and Flt levels between May 1982 and August 1982 samples suggesting that PAH levels in lobsters do not vary significantly over the course of the commercial lobster fishing season from mid-May to mid-July. Statistical analysis of the South Arm data (F test, P=0.05) showed that there were no significant differences among data from the four sampling periods. This indicates that AH levels in South Arm did not change significantly between May 1981 and August 1982.

The Morien Bay and Mira Bay control sites were chosen due to their relative isolation from any obvious anthropogenic sources of PAH such as wharves, boat mooring facilities, etc. PAH levels in these control lobsters were low, with average B[a]P concentrations in hepatopancreas of 2.1 and 0.3 ng/g for Morien Bay and Mira Bay respectively (Table 7). Only traces of B[a]P were found in control tail muscle. Mean Flt levels in hepatopancreas were 407 and 68 ng/g for Morien Bay and Mira Bay respectively, while the corresponding tail muscle values were 10 and 9 ng/g respectively. These levels are comparable to those found in lobsters from Point Aconi, the sampling site northeast of Sydney Harbour. Average B[a]P levels in Point Aconi lobsters were 0.3 and 0.5 ng/g for hepatopancreas and tail muscle respectively.

PAH levels in lobster from Lingan Bay and Glace Bay (Table 6), though lower than Sydney Harbour levels, were higher than levels at the control sites (Table 7). For example, average B[a]P levels in hepatopancreas were approximately 5 ng/g and 20 ng/g at Lingan Bay and Glace Bay respectively and average Flt levels in hepatopancreas were approximately 300 ng/g and 420 ng/g at Lingan Bay and Glace Bay respectively, while corresponding tail muscle BaP values were 0.5 ng/g and 1.2 ng/g and Flt values were 14 ng/g and 32 ng/g. These levels may reflect both an influence from Sydney Harbour water and local anthropogenic inputs.

Flt/Pyr ratios were calculated, and highly variable ratios were found (Table 8). This could have resulted from exposure of the animals at the various sample sites to PAH of variable composition, animal-to-animal

Table 4. PAH concentrations (ng/g wet wt) in Petrie Point lobster (ng/g wet weight) ('A' pool, 'B' pool).

PAH	OCTOBER 1981		MAY 1982		AUGUST 1982	
Hepatopancreas						
Phen	1530	1280	795	898	582	626
Flt	2320	1940	648	2330	1050	1330
Pyr	1000	730	993	2880	384	776
Tri	4310	4600	3180	4730	1710	3570
B[a]A	3360	1700	1570	5820	1260	2290
Chry	840	478	125	282	135	278
B[e]P	1080	590	296	788	160	700
B[b]F	270	170	192	588	194	324
B[k]F	70	40	39	134	70	88
B[a]P	66	30	60	131	98	145
B[ghi]Pe	46	13	38	40	48	53
I[1,2,3-cd]P	70	36	64	83	49	57
Tail muscle						
Phen	T[c]	T	86	185	51	16
Flt	85	100	75	93	29	32
Pyr	16	27	35	65	6	10
Tri	60	64	106	146	T	T
B[a]A	47	36	80	170	23	38
Chry	3	3.5	4	18	nd[b]	T
B[e]P	T	T	13	19	10	11
B[b]F	5	5	14	19	4.7	7.2
B[k]F	1.6	1.3	3.5	4.7	1.5	1.9
B[a]P	1.6	1.3	4	5	2.7	3.3
B[ghi]Pe	1.4	1	3	5	2.5	2.1
I[1,2,3-cd]P	1.5	1.5	44	4.4	132	1.9

b - not detected
c - trace

Table 5. PAH concentrations (ng/g wet wt) in Swivel Point lobster ('A' pool, 'B' pool).

PAH	OCTOBER 1981		MAY 1982	
Hepatopancreas				
Phen	990	1260	600	325
Flt	1910	2000	1290	533
Pyr	910	1260	347	366
Tri	5890	5840	1420	1670
B[a]A	3010	3580	700	615
Chry	1000	895	36	28
B[e]P	1510	1580	179	103
B[b]F	295	272	117	66
B[k]F	75	63	41	23
B[a]P	128	120	37	20
B[ghi]Pe	283	105	26	13
I[1,2,3-cd]P	205	140	36	15
Tail muscle				
Phen	175	155	82	114
Flt	145	103	44	57
Pyr	180	110	13	15
Tri	160	106	78	71
B[a]A	165	152	13	29
Chry	51	31	7	11
B[e]P	50	42	11	8
B[b]F	11	9	5	3
B[k]F	2.4	2.4	1	0.8
B[a]P	3.7	4.6	1.8	0.9
B[ghi]Pe	3.4	5	2.7	2.4
I[1,2,3-cd]P	4	4	1.8	1.4

Table 6. PAH concentrations (ng/g wet wt) in Point Aconi, Black Point, Low Point, Lingan and Glace Bay lobsters sampled in October 1981.

PAH	Point Aconi		Black Point		Low Point		Lingan Bay		Glace Bay	
Hepatopancreas										
Phen	5	6	310	350	T	285	T	T	100	92
Flt	30	33	350	320	1100	1200	340	256	460	381
Pyr	15	22	163	245	365	260	T	T	120	110
Tri	T[c]	T	190	206	1250	T	T	T	210	221
B[a]A	5.8	2.5	575	60	550	418	85	42	400	278
Chry	T	T	45	17	127	57	35	20	90	101
B[e]P	2.7	5.6	120	42	330	137	100	20	220	119
B[b]F	1.7	2	56	11	175	29	26	10	44	31
B[k]F	0.5	0.6	12	2.6	55	8.1	9	3	11	12
B[a]P	0.1	0.5	8.4	2	60	4.5	7	2.5	19	22
B[ghi]Pe	T	1.9	18	7.8	54	11	8	2.5	17	19
I[1,2,3-cd]P	T	1.9	8	3.4	109	10	8	5.5	36	31
Tail muscle										
Phen	62	T	24	T[d]	148	146	14	11	16	8
Flt	75	2	5	4	129	99	14	13	38	26
Pyr	T	25	T	nd	119	124	3	nd	d	7
Tri	nd[b]	T	nd	nd	82	119	T	nd	7	T
B[a]A	nd	T	3	T	36	23	4	4.5	30	32
Chry	nd	T	T	nd	11	8.5	1	0.7	3	1
B[e]P	nd	T	T	nd	20	10.2	4	2	8.5	7
B[b]F	0.5	0.6	1.3	0.5	14	1.7	1.5	1.6	3.5	2
B[k]F	0.5	0.5	0.5	0.5	3.4	0.4	0.5	0.5	0.7	0.6
B[a]P	0.5	0.5	0.5	0.5	5.2	0.6	0.5	0.5	1.5	0.8
B[ghi]Pe	nd	1.8	0.5	T	3.8	2.5	1	0.1	1.7	0.7
I[1,2,3-cd]P	nd	0.6	0.7	0.6	5.2	1	0.7	1	0.4	1.2

b - not detected
c - trace
d - peak uncertainty

Table 7. PAH concentrations (ng/g wet wt) in Morien and Mira Bay (Control) Lobsters samples in October 1981.

PAH	MORIEN BAY	MIRA BAY	
Hepatopancreas			
Phen	345	20	30
Flt	407	46	90
Pyr	197	nd[b]	T[c]
Tri	141	nd	T
B[a]A	38	9	26
Chry	12	2.5	9
B[e]P	23	12	17
B[b]F	6.5	3	6
B[k]F	1.9	0.8	1.4
B[a]P	2.1	0.4	1
B[ghi]Pe	6.8	1.4	2.4
I[1,2,3-cd]P	5	2.1	4
Tail Muscle			
Phen	15	nd	5
Flt	10	12	5.5
Pyr	5	nd	nd
Tri	T	nd	nd
B[a]A	T	133	9
Chry	T	14	nd
B[e]P	T	22	nd
B[b]F	T	5.3	0.7
B[k]F	T	1.6	T
B[a]P	T	2	T
B[ghi]Pe	T	2	T
I[1,2,3-cd]P	nd	3.7	nd

b - not detected
c - trace

Table 8. Flt/Pyr ratios in lobster hepatopancreas (HP) and tail muscle (TM) (HP-A,HP-B/TM-A,TM-B).

Site	MAY 1981	OCTOBER 1981	MAY 1982	AUGUST 1982
South Arm	0.9,0.81/2.00	1.85,3.6/2.06,3.2	1.16,1.36/1.26,6.3	1.05,1.15/1.23,1.09
South Bar	1.57,1.32/-g	2.63,2.53/3.43,3.57	2.52,2.87/7,5.7	1.98,1.15/1.94,3.75
Northwest Arm		3.89,3.64/2,1.69	3.6,0.81/5.7,5.42	
Petrie Point		2.32,2.66/5.31,3.7	0.65,0.81/2.14,1.43	2.73,1.71/4.8,3.2
Swivel Point		2.1,1.59/0.81,0.94	3.72,1.46/3.38,3.8	
Low Point		3.04,4.62/1.08,0.8		
Point Aconi		2,1.46/-,0.08		
Black Point		2.14,1.31/-,-		
Lingan Bay		-,-/4.67/,-		
Glace Bay		3.83,3.46/-,3.71		
Morien Bay		2.07,/2		
Mira Bay		-,-/-,-		

g = Ratios unable to be calculated due to "trace" or "not detected" amounts.

differences (Table 10), or from the presence of interfering materials in the analytical extracts or the analytical methodology itself. The analytical methodology has been applied to determining PAH in lobster exposed to a synthetic mixture of five pure PAH in water (McLeese and Burridge, 1984). Following 72 h uptake, the Flt/Pyr mean ratios were 0.26±0.071 (relative standard deviation 27%) and 0.92±0.11 (relative standard deviation 12%) for the hepatopancreas and tail muscle respectively (N=6 in both cases) (data by permission of D. McLeese). The data from the South Arm samples showed an overall Flt/Pyr mean ratio of 1.49±0.91 (relative standard deviation 61%) and 2.45±1.85 (relative standard deviation 75%) (Table 8) for hepatopancreas and tail muscle respectively. It is likely that PAH inputs to Sydney Harbour are highly variable, being dependent on climatic conditions and discharges from the Steel Plant and Coking Oven complex. Lobsters also wander, thus introducing a further heterogeneity. The likelihood of interfering material in the analytical extracts is high given the extremely heterogeneous nature of the PAH composition of coal tar (Uthe 1979), however the combination detection system (fluorescence and UV absorption) did not suggest the presence of significant interferences. A superior separation/detection system such as capillary gas chromatography/mass spectroscopy is needed to further resolve the sources of the variance.

Analysis of lobsters from "clean" and "dirty" areas showed in general, there was little difference in PAH levels in lobsters from "clean" areas (Table 9). For example B[a]P levels in hepatopancreas ranged from 1.6 ng/g in a "clean" area of Morien to 30 ng/g in a "clean" area of Guysborough, while tail muscle levels ranged from 0.5 ng/g in the Morien "clean" sample to 2.7 ng/g in the Louisbourg "clean" sample. Flt levels in hepatopancreas ranged from 143 ng/g at the Morien "dirty" site to 435 ng/g at the Louisbourg site, while tail muscle levels ranged from 6-34 ng/g in the two tissue pools from the Morien "clean" site and 8-14 ng/g at the Morien "dirty" site.

Table 11 gives PAH levels in uncooked crusher claw, pincer claw, and tail muscle from three individual lobsters from the South Arm. In general, PAH levels in claws are somewhat lower than in corresponding tail muscle, with pincer and crusher claws having comparable levels.

Five PAH were measured in raw and cooked tissues (Table 12). There was a dramatic increase in PAH levels in the tail muscle when the lobster was cooked whole. There was also a decrease in the corresponding hepatopancreatic PAH levels compared with levels in the raw tissue although it must be emphasized that the cooked hepatopancreas contained clotted hemolymph and other tissue residues. PAH levels in tail muscle cooked after separating it from the body portion were not significantly different from levels in the raw tissue. It is evident from this cooking study that hepatopancreas behaved as a PAH source when lobster were cooked whole. Although only 5 PAH were measured in this experiment, it is reasonable to assume that the other 7 PAH will behave in a similar manner since the 5 measured PAH span the approximate range of molecular sizes and water solubilities of the 12 PAH measured in the main part of the survey (Neff, 1979).

Table 9. PAH concentrations (ng/g wet wt) in background lobster.

	Port Morien "Clean"		Port Morien "Dirty"		Guysborough "Clean"		Louisburg "Clean"	
Hepatopancreas								
Phen	145	175	124	91	60	128	86	30
Flt	156	162	147	143	400	390	400	435
Pyr	42	46	33	41	148	130	18	21
Tri	188	156	135	150	180	135	147	120
B[a]A	79	74	45	43	480	720	157	135
Chry	7	2	7	6.8	126	360	25	11
B[e]P	17	15	15	15	154	517	75	33
B[b]F	10	7	9	10	30	60	35	12
B[k]F	2.8	1.9	2.2	2.5	8	18	7.7	4
B[a]P	2.5	1.6	2.5	2.7	13	30	6	5
B[ghi]Pe	2.4	3.8	3.2	4	7	24	7.5	4
I[1,2,3-cd]P	2.1	2.5	2.6	2.5	16	74	25	14
Tail muscle								
Phen	10	67	38	74	12	20	2	28
Flt	6	34	8	14	32	23	12	32
Pyr	T[c]	22	2	22	T	10	T	7
Tri	22	36	28	56	T	15	nd	44
B[a]A	6	17	8	61	25	30	3.4	140
Chry	T	T	T	T	3	1	1.5	11
B[e]P	2.5	36	2	25	6.5	1	T	30
B[b]F	0.5	0.8	0.5	1	3	4	1.3	9
B[k]F	0.5	0.8	0.5	0.6	0.8	1	0.5	2.6
B[a]P	0.5	1.6	0.5	1	1.5	1.5	0.5	2.7
B[ghi]Pe	0.8	nd[b]	0.5	7	2	1	0.5	2.6
I[1,2,3-cd]P	0.8	nd	T	0.5	1.5	1.5	0.6	4

b - not detected
c - trace

Table 10. PAH concentrations (ng/g wet wt) in individual lobster hepatopancreas following 3 month exposure to creosoted timbers and transfer to clean water for 13 days.

	Hepatopancreas										
number	1	2	3	4	5	6	7	8	9	10	RSD
Phen	1980	2000	720	700	1100	3400	390	1600	3100	3000	66
Flt	3800	6700	3400	2100	3400	10300	6500	7100	10600	8500	48
Pyr	1300	3000	1200	420	1400	5500	1800	2400	2700	3500	63
Tri	11500	8200	7800	4100	6700	32400	15200	24700	39000	18700	69
B[a]A	6200	8100	4900	2000	4500	20000	9500	17500	19400	19600	64
Chry	5600	5300	3600	1800	3100	17800	7200	16100	16700	17600	70
B[e]P	1200	500	360	210	250	1600	780	1200	1400	1200	59
B[b]F	790	630	440	370	390	2000	950	2100	1800	1800	63
B[k]F	200	160	110	100	100	530	250	520	450	440	63
B[a]P	220	150	140	100	140	860	270	830	680	740	78
B[ghi]Pe	340	240	240	140	240	1600	400	1700	1300	1400	86
I[1,2,3-cd]P	1000	690	560	390	500	4300	1300	4300	2900	3300	83
Flt/Pyr	2.9	2.2	2.8	5	2.4	1.9	3.6	2.9	3.9	2.4	31
	Tail Muscle										
Phen	300	140	280	270	180	210	220	260	310	200	21
Flt	90	97	180	99	67	180	200	210	230	240	40
Pyr	10	35	56	22	29	83	47	57	61	78	47
Tri	280	150	430	320	200	650	550	820	320	590	48
B[a]A	200	210	260	130	100	370	410	560	310	370	46
Chry	190	130	160	110	60	290	280	430	200	250	50
B[e]P	30	14	20	10	10	36	30	45	22	30	45
B[b]F	30	20	26	27	9	42	46	72	31	35	48
B[k]F	7	4	7	7	2	11	13	19	9	10	51
B[a]P	8	5	10	12	4	21	19	32	15	16	57
B[ghi]Pe	15	8	15	17	6	39	29	59	24	25	64
I[1,2,3-cd]P	45	21	34	44	12	100	78	170	60	59	70
Flt/Pyr	9.1	2.8	3.2	4.5	2.3	2.2	4.3	3.7	3.8	3.1	51

e-relative standard deviation

Table 11. PAH concentrations (ng/g wet wt) in pincer and crusher claw and tail muscle from individual south arm lobsters.

Sample No.	South Arm No. 1			South Arm No. 5			South Arm No. 10		
Sample Type	Tail	Pincer	Crusher	Tail	Pincer	Crusher	Tail	Pincer	Crusher
Phen	80	30	37	163	146	81	100	79	88
Flt	128	51	55	198	183	174	181	155	193
Pyr	81	22	28	208	182	135	131	92	124
Tri	37	nd[b]	nd	141	62	21	64	43	57
B[a]A	211	86	94	317	233	207	202	135	181
Chry	6.9	T[c]	T	7.8	2.5	0.6	2.9	T	T
B[e]P	16	4	3.3	57	50	38	50	27	44
B[b]F	24	7.6	9.3	54	47	43	51	35	52
B[k]F	8.3	2.5	3.2	12	11	11	12	8.2	12
B[a]P	33	8.5	11	55	45	44	55	43	58
B[ghi]Pe	15	2.9	4.7	31	22	18	43	26	37
I[1,2,3-cd]P	16	4.2	5.1	35	24	23	37	21	33

b - not detected
c - trace

Table 12. PAH concentration in raw and cooked lobster tissues (ng/kg wet wt)
PAH levels in raw lobster tissues.

Sample type	Tail muscle		Hepatopancreas	
Sample pool	A	B	A	B
Phen	128	134	5730	5880
Flt	148	150	1350	2360
Pyr	151	214	5430	5500
Tri	15	40	666	941
Per	19	73	1230	1220

PAH Levels in Separately-Cooked Lobster (Tail Muscle)

Sample type	Tail muscle	
Sample pool	A	B
Phen	177	138
Flt	152	151
Pyr	203	230
Tri	35	21
Per	84	71

PAH Levels in Lobster Tissues from Lobster Cooked Whole

Sample type	Tail muscle		Hepatopancreas	
Sample pool	A	B	A	B
Phen	1430	1430	525	672
Flt	207	224	704	742
Pyr	1020	939	595	742
Tri	1040	964	T[c]	100
Per	292	323	147	306

c = trace

Table 13. Analytical data on presence of additional carcinogenic PAH in south arm lobster hepatopancreas (August 1982 sample, ng/g wet wt).

PAH	Concentration
dibenzo[a,h]pyrene	not present
dibenzo[a,i]pyrene	not present
benzo[j]fluoranthene	not present
dibenz[a,h]anthracene	300-600
7,12-dimethylbenz[a]anthracene	1[f]

f = requires GC/MS confirmation

Table 14. PAH concentrations (ng/g wet wt) in Sydney area mussels 1981-1982 sample.

1981

	South Bar	Bridgeport Basin	Homeville Bridge	Alder Point	Seal Island
Phen	900	nd[b]	nd	625	900
Flt	4600	87	77	416	43
Pyr	1060	nd	323	T[c]	nd
Tri	nd	nd	nd	260	T
B[a]A	10500	60	240	700	75
Chry	13100	97	273	925	T
B[e]P	4800	nd	nd	240	T
B[b]F	765	12	T	53	3
B[k]F	215	1	T	8	3
B[a]P	195	T	T	5	T
B[ghi]Pe	1130	8	30	34	T
I[1,2,3-cd]P	1610	6	43	25	nd

1982

	South Bar	Bridgeport Basin	Homeville Bridge	Alder Point	Seal Island
Phen	2150	102	T	47	nd
Flt	1230	68	46	25	14
Pyr	1760	24	T	24	nd
Tri	3240	66	T	125	nd
B[a]A	4140	95	9	41	nd
Chry	217	T	nd	T	nd
B[e]P	427	T	nd	T	nd
B[b]F	216	3.5	0.8	2.3	T
B[k]F	73	1.5	0.2	0.6	T
B[a]P	226	4.6	0.2	1.3	nd
B[ghi]Pe	84	1.2	nd	T	nd
I[1,2,3-cd]P	192	4.4	0.3	1.1	nd

b = not detected
c = trace

The presence of five additional carcinogenic PAH was investigated in a sample of South Arm hepatopancreas collected in August 1982 in (Table 13). Dibenzo[a,h]pyrene, dibenzo[a,i]pyrene and benzo[j]fluoranthene were not detected. The levels of both dibenz[a,h]anthracene and 7,12-dimethylbenz[a]anthracene are estimates only.

Table 14 shows the results of PAH analyses of blue mussels (Mytilus edulis) sampled in Sydney Harbour and surrounding areas (Fig. 2) in 1981 and 1982. An extremely wide range of values was obtained ranging from 221 ng/g B[a]P in the South Bar samples to trace levels in the Seal Island samples while Flt levels averaged 2915 and 29 ng/g respectively. It should also be noted that the physical appearance and abundance of mussels was extremely variable between 1981 and 1982. In 1981 at Alder Point, mussels were very plentiful in a complete range of sizes, whereas in 1982 they were scarce and of a smaller size. This difference in abundance between the two sampling years was also evident at Seal Island. In 1981, mussels were quite abundant, though of a relatively narrow size range, along the entire shoreline of the sampling area. In 1982, very few mussels could be found, and there were extensive areas completely devoid of mussels or empty shells. Seal Island mussel shells also were thin and easily broken in both years. The Homeville Bridge site also showed this apparent population decrease in 1982 although a to a lesser extent. In general, at all sample locations except Bridgeport Basin, PAH levels were considerably lower in 1982 than in 1981. Sampling of mussels was done during the same time period each year, early May, and the generally lower 1982 PAH levels and decreased abundance may be related to the colder climatic conditions prevalent in the early part of 1982 compared to the same period in 1981. The exception to this difference between the 1981 and 1982 samples is Bridgeport Basin, which showed a slight increase in PAH levels for 1982. Whether or not this increase is significant will be checked in future samplings of mussels at this site.

In conclusion the relative consistency of PAH levels in Sydney harbour lobsters sampled through 1981 and 1982 indicates that the contamination of the inner harbour appears to be a relatively stable and long-term situation, and that the closure of the South Arm to commercial lobster fishing is likely to continue for some time.

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POOR

QUALITY

ORIGINAL